PRODUCTION OF A SPIN-POLARIZED ATOMIC Cr BEAM USING OPTICAL PUMPING METHODS

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Over the past decade or so, laser optical pumping has seen increasing usage as a method for producing state-selected, aligned, oriented, or spin-polarized atomic species for collision studies. Because of the necessity of having an atom which (1) has an appropriate level structure, (2) has a transition accessible to available lasers, and (3) can be produced in an atomic beam without significant contaminants or dimers, optical pumping studies have so far been limited to alkali atoms, some alkaline earths, and some metastable rare gas species. In the present work, we have successfully applied the techniques of optical pumping for the first time to a transition metal, i.e., Cr.

The motivation for optically pumping Cr, besides the fact that it is a type of atom never before optically pumped, lies in its unique spin configuration. The ground state of neutral Cr has the atomic configuration (Ar)$3d^5 4s^1 (^7S_3)$. This septet configuration means that the atom has a half-filled d-shell, in which all the spins are aligned, and also a half-filled s-shell, in which the spin of the electron is aligned with the spins of the electrons in the d-shell. Thus an optically pumped ground state Cr atom represents a novel type of spin-polarized atomic target: one in which there are six electrons, all with spins oriented in the same direction in space. An optically pumped excited state Cr atom has the same spin configuration, coupled with an orbital angular momentum of $L = 1$.

Optical pumping of Cr is carried out on the $^7S_3 \rightarrow {}^7P_4^o$ transition at 425.43 nm (see Figure 1). The necessary laser radiation is produced with a UV-pumped single-frequency, stabilized ring dye laser utilizing stilbene 420 dye. Single frequency output is typically 200-300 mW with 4.5 W pump power. There is no hyperfine structure in the most abundant isotope of Cr (84% ^{52}Cr), so the optical pumping is carried out on a $J = 3 \rightarrow J' = 4$ transition. Using circularly polarized light, the ground state population is transferred from an initially isotropic distribution across the M_J levels to a pure $M_J = \pm 3$ state for $\sigma^{\pm}$ light. The excited state population is similarly concentrated into a pure $M_J = \pm 4$ state as long as the laser light continues to interact with the atoms.

The Cr atomic beam is produced in a high temperature oven containing an electron-beam heated Ta cell filled with 80 g of Cr crystals. Operating temperatures range from 1200–1500 °C. At these temperatures, Cr sublimates inside the cell and effuses through a 1 mm opening. Atomic fluxes as high as 6×10^{19} atoms $m^{-2}s^{-1}$ have been obtained at a distance of 200 mm from the oven aperture.

The spin polarization of the optically pumped Cr beam is diagnosed by measuring the polarization of the laser induced fluorescence generated in a probe region located downstream in the atomic beam.[1] Measurements show that the ^{52}Cr population of the atomic beam is 95% spin-polarized or better.

The spin-polarized Cr atomic beam will be used for collision studies with spin-polarized electrons. Previous studies on Na have allowed the determination of the relative strengths of the the singlet and triplet scattering channels in the elastic[1, 2] and superelastic[3] state. In studying Cr, we will be investigating how these processes generalize to high-spin atoms.

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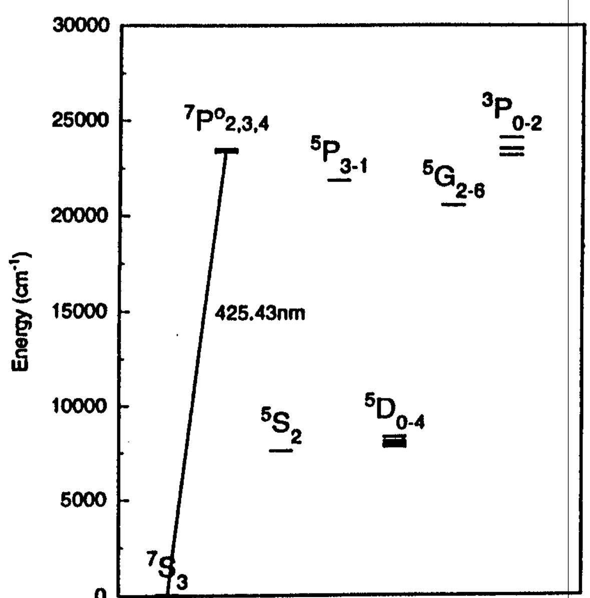

FIGURE 1: Atomic energy levels of neutral Cr, showing optical pumping transition.

References

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